Assessment of Baseline Soil Carbon Sequestration Using an Econometrically Estimated Model of Conservation Tillage

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Introduction

Conservation tillage (CT) is regarded as one of the most effective practices for increasing carbon content in many agricultural soils. Since many farmers use CT without any policy intervention, a key question associated with any policy designed to increase the adoption of CT to induce higher carbon sequestration is the amount of carbon that can be directly credited to the program versus that which would have occurred anyway. To address this question, a baseline that represents "business as usual" (BAU) conditions is needed to rightfully account for the additional carbon generated due to a policy.

Study region and data

The Upper Mississippi River Basin (UMRB) is a large watershed at the head of the Mississippi River covering parts of the central U.S. Cropland and pasture are the dominant land uses in the UMRB and account for about two-thirds of the total area. The watershed is comprised of 14 sub-watersheds that coincide with the boundaries of U.S. Geological Survey Hydrologic Units, commonly referred to as 4-digit Hydrologic Unit Codes (Figure 1).

The primary data used in the study are from the 1997 Natural Resource Inventory (NRI) (Nusser and Goebel, 1997), which provides information on soils, cropping history, and conservation practices over the entire region from 1982 to 1997.

Study Objectives and Methodology

We develop a methodology for estimating a carbon sequestration baseline attributable to the current use of CT. An integral component of the methodology is the explicit acknowledgment that there is an uncertainty in the baseline because of the uncertainty associated with the use of econometrically estimated models. The results of applying the method to UMRB are reported for two major crops, corn and soybeans. In addition, we recognize that the BAU baseline may also be driven by changes in various exogenous variables that themselves drive changes in the underlying adoption rates of CT over time. Thus, we also derive baseline estimates under predicted potential changes in farmer characteristics and fuel prices.

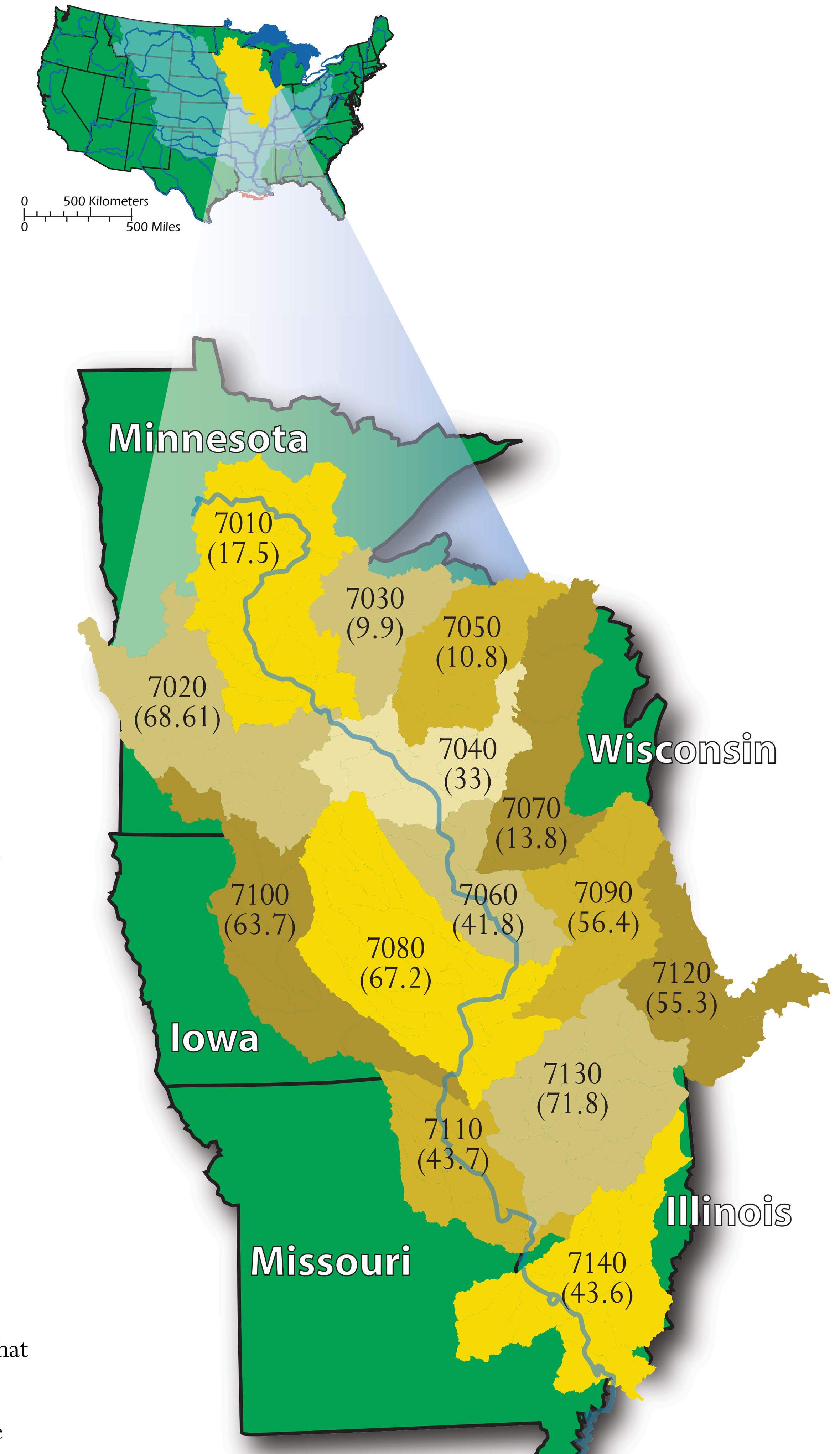

Figure 1. Upper Mississippi River Basin (UMRB) Subdivided into USGS 4-digit Watersheds: Percentage of Area Under Cropland

Estimation of the CT and Carbon Sequestration Baseline

Five steps in developing the baselines:

1) Econometrically estimate a CT adoption model for each sub-region of the UMRB.

The basic model from Kurkalova et al. (2006) assumes that a farmer adopts CT when the net returns to farming using CT exceed the net returns to the conventional practice plus a risk premium. Assuming a logistic error and alinear net returns and premium function, the coefficients of the model are recovered using the method of maxium likelihood. The model is estimated using data from 1992—the latest year that tillage data is reported.

2) Calibrate the estimated model to the most recent data on CT adoption rates available.

The 1997 region-average CT use estimates derived from Agricultural Resource Management Survey data (http://www.ers.usda.gov/data/arms/) and county-level estimates reported by the Conservation Technology Information Center (http://www.ctic.purdue.edu/CTIC/CTIC.html) are used to calibrate the model, estimated in step 1. The values of the parameters are chosen so that the region-average model-predicted rate of adoption of CT is equal to that derived from the CTIC and ARMS data.

3) Combine the adoption model estimates with field-specific carbon sequestration estimates to generate a BAU carbon baseline.

We assess the carbon sequestration potential of each cropland NRI point using the Erosion Productivity Impact Calculator model (Williams, 1990) and then combine the carbon estimates with the estimates of the probabilities of CT adoption from the calibrated model. The NRI-point- level carbon sequestration estimates are computed as the annual average difference of the total soil carbon pool under two scenarios: one assuming 30 years of CT and the other assuming 30 years of conventional tillage.

4) Generate confidence intervals around these point estimates using a bootstrap-like procedure of Krinsky and Robb (1986).

Interestingly, we found tight confidence bounds on the baselines both for each watershed (Figure 2) and for the UMRB area as a whole (Figure 3). As expected, the baseline point estimates differ significantly across watersheds, reflecting the differences in soils, landscape, and other factors affecting crop production and CT adoption, as well as in the area under crops.

5) Relax the BAU assumption and derive baseline estimates under changes in farmer characteristics and fuel prices.

We use Census of Agriculture (http://www.nass.usda.gov/census/) county-level data to estimate the 1992 to 1997 change in four explanatory variables of the CT adoption model: proportion of county cropland operated by tenants, proportion of county operators working off farm, county-average farm operator age, and proportion of county operators that are male, separately for each county in the analysis. The estimates of the changes are then used to predict the values of the four explanatory variables in 2007 under the assumption that the identified linear trend will continue. As evident from Figure 3, the changes are large.

Somewhat surprisingly, we do not find a significant effect of the fuel price changes on the baselines, as reflected in the large overlap of the corresponding histograms in Figure 4.

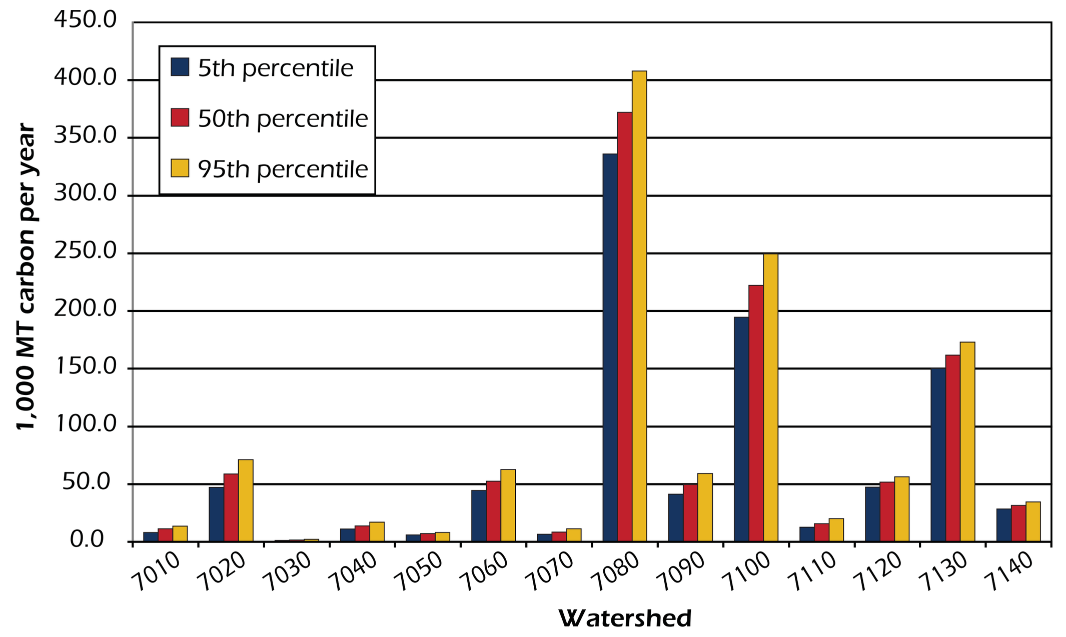

Figure 2. BAU Baseline, by Watershed

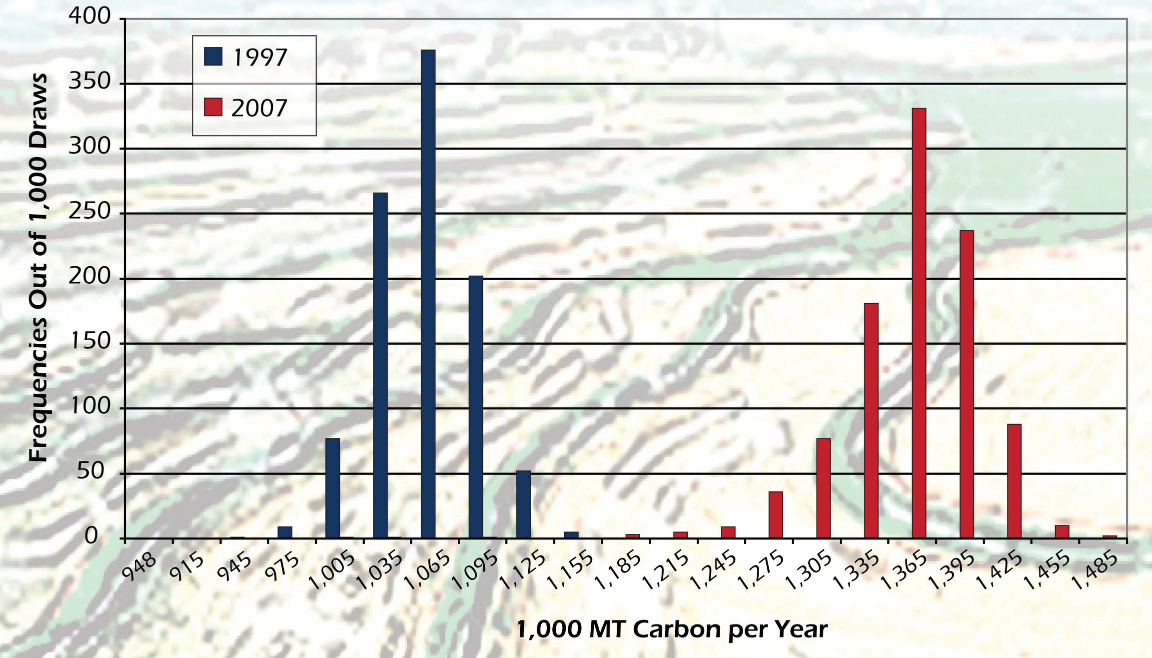

Figure 3. Effect of Changes in Farmer Characteristics on UMRB Baseline: 1997 Versus 2007

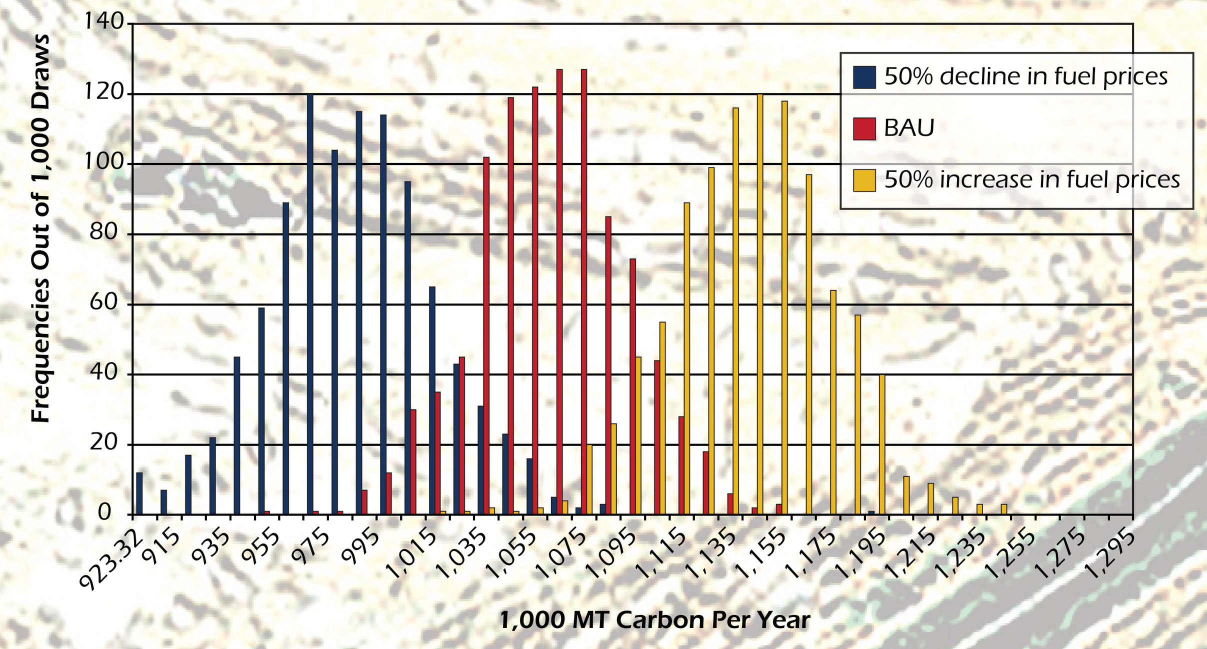

Figure 4. Effect of Fuel Price Changes on UMRB Baseline

Conclusions

- This study proposes a methodology for developing a carbon sequestration baseline resulting from the adoption of CT.
- In an application of the methodology to UMRB we find wide variations in the BAU baselines across the 14 sub-watersheds in the study region. This finding points out the importance of using models that capture the full spatial heterogeneity of soil, weather, and other characteristics in establishing baseline estimates.
- A finding of note is that the BAU can change considerably when explicit recognition is taken of the fact that average farmer characteristics, fuel prices, and other economic factors will be changing in the future. This clearly indicates that if account is not taken of these non-policy changes, the baseline will be incorrectly specified.
- Further studies will be performed to expand our analysis to crops other than corn and soybeans.

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